The Dust Catcher: Discovering the Educational Value of the Historical Scientific Heritage

The dust catcher: Discovering the educational value of the historical scientific heritage

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Abstract. The purpose of this work is to present a physics education project, conducted at the University of Turin, whose goal is studying the educational significance of the history of physics and, in particular, of the history of scientific instruments. In this project, the survey of the scientific collection of the Museum of Physics of the University of Turin is followed by a census of the collections of physics instrument of historical-scientific interest preserved by a sample of schools in Piedmont. The third part of the project is devoted to explore the expectations of in-service teachers on the usefulness of the history of physics for educational purposes and to design and test hands-on activities on electric phenomena inspired by the historical devices preserved by the Museum of Physics. In this paper we present the preliminary results of this latest part of the project.

By this project we aim to show that the dusty equipment of the old Physics Cabinets of universities and schools, if appropriately studied and re-designed, could again serve an educational function, that is they might provide us a better insight into student's prior knowledge and at the same time promote a better understanding of physical sciences.

Keywords: History of physics. Historical scientific heritage. Museum of Physics

1 Introduction

This paper is part of a PhD physics education project devoted to the study of the educational significance of the history of physics. More specifically, this project aims at developing the relationship between the Museum of Physics of the University of Turin and the old Cabinets of Physics of secondary schools in Turin and Cuneo provinces, in north western Italy. General objectives of the project are: survey of the scientific collection of the Museum of Physics, including the instruments not yet catalogued; census of the collections of physics instrument of historical-scientific interest preserved by the schools in Piedmont, with a focus on the most ancient types of public and private secondary schools likely preserving scientific collections, i.e. classical lyceum and technical institutes; collection of teacher's expectations about the historical approach and design of inquiry-based educational activities rooted in the development of the physics instruments displayed in the Museum and in the other scientific collections identified with the goal of providing us a better insight into student's prior knowledge and promoting a better understanding of physical sciences.

The specific activities performed in the schools, in collaboration with the (about) 20 teachers participating to the project (i.e. roughly one per each of the oldest classical lyceums in Turin and Cuneo provinces), are largely dependent on the current state of organization of the local cabinets of physics: experimental activities inspired by the local collection are designed and tested when the collection is relatively well surveyed and catalogued; on the contrary, when the collection has not yet reached an adequate level of organization, the activities focus on a census of the instruments and on historical researches on the physics behind the instruments. In both cases the students are expected to be active protagonists of the designed intervention.

In this paper, we present the preliminary results of this project with reference to the following research question in mind: is it possible to rediscover again the education value of a dusty collection of scientific instruments?

2 History of Physics as an educational tool

The collections preserved by University-based physics museums are usually made of instruments originally acquired for teaching *or* research. Yet, the sad state of affairs of most of these collections is that these instruments are by and large unused *neither* in research *nor* in teaching. This state of affairs is made even more sad by the growing awareness in the science education community of the science education functions of science museums as well as of the advantages of introducing history of science topics into the teaching of science [17][18]. History and philosophy of science (hereafter HPS) might be a useful tool to help identifying, and possibly overcoming, the mental representation of students on physical science topics [16]. HPS and the wider domain of the history of material culture as represented by the collections of old scientific instruments in schools and universities, may also prove to be useful at the meta-cognitive level. It was indeed argued that the collaboration between school and science museum, i.e. between formal and informal education, might promote achieving both cognitive and emotional student outcomes [4][5]. One of the teaching formats that has been elaborated and evaluated by the science education researchers is just “conducting historical (thought) experiments or replicating actual laboratory procedures, tracing the development of scientific methods, concepts and theories” [1][8][11][13][15]. Furthermore, “historical approaches in science education offer substantial benefits in enabling people to develop scientific literacy and an understanding and appreciation both *in* science and *about* science” [9].

However, as it was recently emphasized [10], “despite the positive educational effects of HPS, an apparent change in science teachers’ attitudes towards it and the availability of HPS teaching resources, its occurrence in science classrooms is limited” [12][17]. While some science teachers do see history as a tool for fostering process skills and for illustrating the procedural aspects of real science, “they seem to lack the professional knowledge, epistemological background and confidence to use HPS to support conceptual learning and to reflect on the contexts and nature of science" [10][14][22].

With the goal of addressing the research question about the education value of a dusty collection of scientific instruments, this project exploits the scientific collection of the Museum of Physics of the University of Turin, Italy [6][20]. The instruments now preserved by the Museum are over 1,000, catalogued in part. About 45% of them are exhibited in 23 showcases in the corridors of the old Institute of Physics and in 23 showcases in the Wataghin Hall, the old library of the Institute (see Fig. 1).

Most of the collection is devoted to instruments on electricity, magnetism and optics. This outcome is largely the result of the growing interest in 18th and 19th century physics toward the emerging fields of electricity and electromagnetism studies. This was especially true at the University of Turin, where the research and teaching activity of physicists like Father G.B. Beccaria and Abbè Nollet, in the 18th century, G.D. Botto, in the 19th century, and the skill of instrument makers like E.F. and C. Jest, in the 19th century as well, much contributed to the collection of the Physics Cabinet.

The specifics of the collection of the former Physics Cabinet of the University of Turin make therefore the present museum an ideal place to carry on an historical-educational research focused on electricity topics.

Fig. 1. The "Wataghin Hall" at the 1st floor of the old Institute of Physics.

3 Teacher's expectations about the historical approach

In order to investigate the motivations that drive (or discourage) the choice of using the historical approach to introduce scientific themes and concepts, since Spring 2017 we have been administering a Likert scale questionnaire to a sample of (mainly) secondary school in-service teachers participating to training seminars in physics education organized by the University of Turin. The data collection is ongoing, however the preliminary results obtained from a sample of 78 in–service teachers are of sufficient interest to warrant their presentation.

On a 1 to 5 scale (where 1 corresponds to complete disagreement and 5 to perfect agreement), most of the teachers were in agreement (average 4,1) with the statement that "it is helpful to bring a historical approach to normal disciplinary teaching to show the technological evolution of instrumentation" (see Fig. 2).

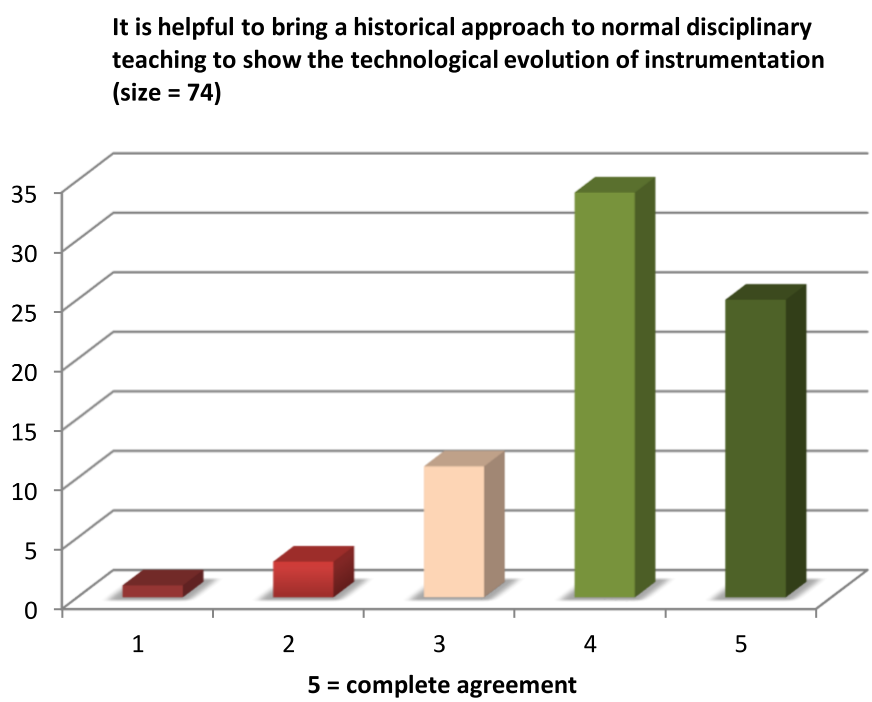

Fig. 2. Teacher's expectations about helpfulness of the historical approach.

The questionnaire attempted, in particular, to address the possible limitations of the historical approach. Interestingly, on this issue most of the teachers showed disagreement with the statement "it is not helpful to bring a historical approach to normal disciplinary teaching because I do not have the necessary preparation" (average 2,2). According to this sample of teachers, a much more important factor is the lack of time: most teachers answered 2 (disagree) or 3 (indefinite) to the sentence "it is not helpful to bring a historical approach to normal disciplinary teaching because it would take too much time" (average 2,2). Finally, the questionnaire addressed the teacher's self-evaluation of their skills. Although most of this sample of teachers were confident that the preparation they had obtained by self-study research was adequate (average 3,6), most of them felt that they had not received an adequate preparation in history of physics for educational purposes during the undergraduate years (average 2,2).
On the whole, these preliminary results suggest that the teachers more active in the in-service training activities do not question the validity of the historical approach but, rather, fear that factors like the lack of time or the lack of adequate preparation in the undergraduate years might compromise the outcome of this approach [20].

4 Student's prior knowledge

With the goal of assessing the educational significance of history of physics and history of scientific instruments, since Fall 2016 we have been offering to secondary schools (mostly grade-12 students from scientific lyceum classes) a one-day programme including a guided visit to the Museum of Physics and a workshop with easy inexpensive materials to make scientific instruments inspired to the collection of the Museum and, in particular, to the instruments about electricity.
Each session of work starts with a semi-structured questionnaire designed to detect student's prior knowledge about the physics contents later addressed in the workshop and, at the same time, to explore if history of physics can help us identifying aspects of such student's prior knowledge. Most items are indeed designed on the basis of the historical evolution of electricity studies with the goal of understanding if the possible difficulties experienced by students are historically rooted.
In the questionnaire are indeed explored student's prior knowledge about subjects like:

- the universal validity of the third Newton's law, i.e. also to the case of rubbing plastic rods (e.g. early fathers of electrostatics like G. Cardano and W. Gilbert, XVI century, believed that "amber is not attracted in turn by a straw") [3][7];

- rubbing vs. heating as the actual cause of the attraction in rubbing experiments (for Gilbert "amber does not attract by heat", however he did not discard the idea that the heat produced by friction is a relevant factor to obtain attraction) [7];

- the air as the agent responsible for the attraction/repulsion electrostatic effects (as it was argued by the Jesuit natural philosopher N. Cabeo) [2];

- the electrification as a phenomenon involving the space surrounding the rubbed object (e.g. Nollet) [19];

- the principle of charge conservation [21].

The above subjects are addressed by proposing to the student a number of experimental situations. By way of example, in one of these situations, a plastic rod is repeatedly rubbed with a wool cloth; after approaching the rod to some paper bits we notice that the bits stick to the rod. This problematic situation is followed by a number of statements about whom the student has to express his agreement or disagreement (true/false) and explain the reasons for his answer. Interestingly, 27% of the sample (size 54 students) answered that the attraction of the paper is caused by the heat produced by friction.
In another situation, a rubbed plastic rod is approached by a small ball of elder wood hanging on a cotton thread (i.e. a device like the many XVIII century electrostatics pendulums displayed in the Museum of Physics). We see the ball approaching the rod, touching it and then moving away. According to 18% of the sample, the ball approaches the rod because it is pushed by the air that tends to head towards the rod due to the effect that the rubbing has produced around the rod. Finally, 53% of the sample expressed disagreement with the idea that the ball moves away because on the rod and the ball there are electric charges of the same sign.
These very preliminary results, besides their intrinsic interest for the following hands-on activities based on the issued covered in the questionnaires, suggest that suitably shaped experimental situation, rooted in historically much debated conceptual knots, could be very helpful in bringing out students' prior knowledge that otherwise might remain unexplored.

5 Hands-on activities inspired by the museum of physics collection

The one-day programme offered to the schools includes, besides the guided visit to the Museum of Physics where the original instruments are displayed and the administration of questionnaires on students' prior knowledge, also a number of hands-on activities obtained by artifacts inspired on the historical instruments.
These activities are presently focused on electrostatics and electric current phenomena. Students experience what happens when one puts a rubbed plastic rod or rubber balloon close to a light object, what happens if other materials are rubbed, what happens if the rubbed object touches the light object, and so on. The students are therefore immersed directly in the motivating and complex phenomenology, typical of XVII and XVIII centuries, where electrification by rubbing, by conduction and by induction coexisted in an undifferentiated way.
By learning how to build a Leyden jar, like those preserved by the Museum of Physics (see Fig. 3) with low cost, easy-to-find materials (see Fig. 4), the students deal with the phenomenon of electrification by rubbing and have an opportunity to take some "shocks"

and appreciate the significance of the past attempts to “bottle” electricity with the precursor of the modern capacitor.
By the construction of a rudimentary electroscope, inspired to those displayed in the collection, the students experience the struggle for arriving at a quantification of electricity and to the concept of electric charge (see Fig. 5).
Finally, through the voltaic pile and the continuous production of electric current the students experimentally observe how this apparatus differed from those developed in earlier times (an old version of a Zamboni dry cell is preserved in the Museum).
The preliminary results of the satisfaction questionnaire administered at the end of the one-day program show that students have the feeling of having “better understood the link between scientific discovery and evolution of the instruments” (83 %). “The desire to discover how scientific thought has evolved” is increased as well (61 %).

Fig. 3. Two sets of early 1800s dissectible Leyden jars preserved by the Museum of Physics of the University of Turin (inv. n.: 761).

Fig. 4. Construction of low-cost Leyden jars with plastic cups and aluminium foils.

Fig. 5. Electroscopes with glass jars and their covers.

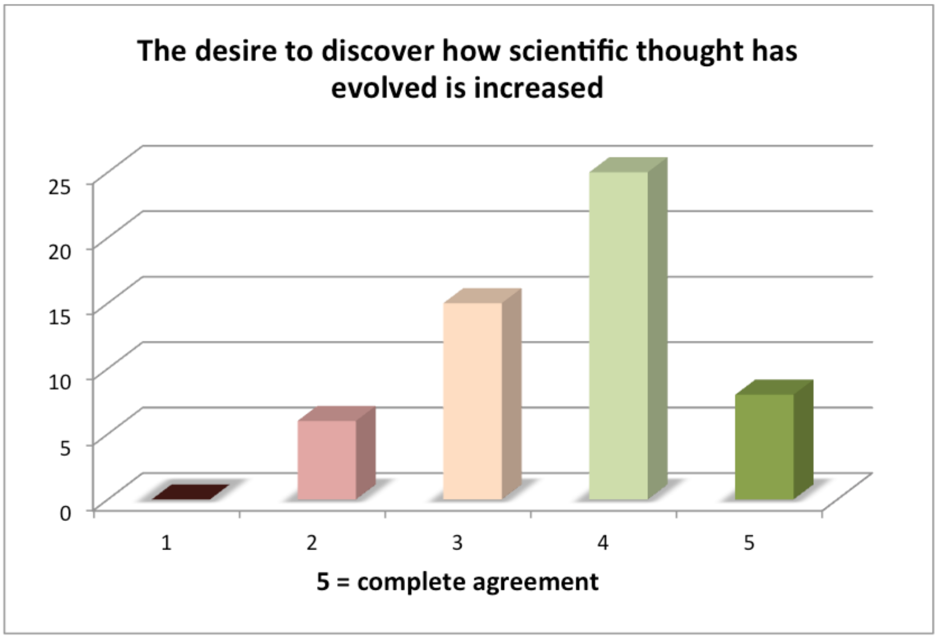

Fig.6. Post-activity students' satisfaction after the one-day program at the Museum of Physics.

CONCLUSIONS

In a very preliminary way, we may conclude that the activities of blowing away the dust out of the "dust catchers" of a typical Museum of Physics collection and developing artifacts inspired by these ancient devices is pretty motivating to students and well accepted by the teachers involved in the project. These activities, also, provide insights into the students' prior knowledge that might prove to be very useful in guiding the next activities in the formal education.

However, although the HPS approach is supported by a "growing body of empirical evidence pointing out positive effects of science lessons enriched by historical information, experiments from past science and historically situated reflections on the [nature of science]" [10], our survey about teacher's expectations also outlines a general lack of confidence of many science teachers in using the HPS approach. Many of the surveyed teachers believe indeed that they had not received an adequate preparation in history of physics for educational purposes during the undergraduate years.

In order to address this issue, the teachers participating to the project are currently engaged in training seminars about set up and organization of a school museum, analysis of students' prior knowledge and instructions on how to prepare a didactic activity using an historical approach. Of course, such an approach would benefit of a much more articulated learning path. The development of teaching pathways to deepen some aspects of the historical approach and to understand how to integrate them into curricular programs is currently ongoing.

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